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REPORT OF TESTS MADE ON THE WESTINGHOUSE PANORAMIX® X-RAY MACHINE

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REPORT OF TESTS MADE ON THE WESTINGHOUSE PANORAMIX® X-RAY MACHINE

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X-ray Exposure Control Laboratory
Division of Electronic Products

March 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Radiological Health
Rockville, Maryland 20852

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FOREWORD

The Bureau of Radiological Health, formerly the National Center for Radiological Health, continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and non-ionizing radiation.

Within the Bureau, the Division of Electronic Products 1) develops and administers performance standards for radiation emissions from electronic products, 2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, 3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and 4) tests and evaluates effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), the Environmental Health Series, Public Health Service numbered reports, appropriate scientific journals, and Division technical reports.

The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The "Radiation Control for Health and Safety Act of 1968" (Public Law 90-602) effective October 18, 1968, provides that the Secretary of Health, Education, and Welfare shall establish an "electronic product radiation control program which shall include the development and administration of performance standards to control the emission of electronic product radiation."

Performance standards are currently under development for diagnostic X-ray equipment used by practitioners of the healing arts. To develop appropriate standards for new X-ray apparatus such as the Panoramix(R) typical operational data must first be obtained.

This report reflects the efforts of the Division of Electronic Products to keep informed of new and unusual types of commercial X-ray equipment and to gather information related to operating characteristics and radiation exposure in the use of such equipment. Measurements made to determine physical and operating characteristics of the Panoramix(R) Model MO-200 X-ray machine are described and the results reported. A study of phantom and patient exposures involved in the clinical use of the Panoramix will be reported in a separate publication in this series.

Robert L. Elder, Sc.D.
Acting Director
Division of Electronic Products

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REPORT OF TESTS MADE ON THE WESTINGHOUSE PANORAMIX(R) X-RAY MACHINE

1. MANUFACTURER'S SPECIFICATIONS

Manufacturer	Westinghouse Electric Corporation
Trade Name	Panoramix(R) Model MO-200
Input	115 volts, 3 amps; 60 Hz
X-ray Tube	Grid-controlled, grounded anode
Focal Spot	0.1 mm
Tube Rating	70 kV at 1 mA
Duty Cycle	30 sec between exposures
Kilovoltage	30 kV to 70 kV in steps of 2-1/2 kV
Tube Current	Fixed, 0.6 to 0.8 mA
Exposure Control	Adjustable, 0.05 mAs to 1.0 mAs
X-ray Beam	Spherical, less 90° shadow of the anode

2. GENERAL DESCRIPTION

The purpose of the Panoramix X-ray machine, as stated by the manufacturer, is "to provide an X-ray tube of such size as to permit it to be used within body openings, either natural or surgical, for the production of radiographs of structures lying between the opening and the skin. It is intended to also provide for the radiography of body protuberances difficult to position for conventional radiography."

The Panoramix Model MO-200 X-ray machine is shown in figure 1. This mobile X-ray unit is mounted on a dolly and can be moved by one person. The tube stand provides vertical and horizontal movement as well as 360^{o} rotation about the vertical column with friction locks for all motions. The gimbal tube mount allows rotation of the tube in the vertical and horizontal planes. A scale on the tube mount shows the angular position of the tube in the vertical plane.

The manufacturer states that the unit must be used with a grounded line supply and should under no circumstances be operated without a safe ground. A blinking light on the right side of the control panel (figure 2) indicates a safe ground connection. When the circuit-breaker type line switch is turned on, a pilot light comes on and after a delay of about one minute a reading appears on the kV meter. Kilovoltages from 30 kV to 70 kV are available in 2-1/2 kV steps through a selector switch and are indicated on a meter which reads 30 to 70 kV full scale. The X-ray tube current is not adjustable at the control panel; the test specifications direct that the filament circuit be adjusted for a tube current of 0.65 mA at 50 kV. Exposure control is by means of an mAs timer adjustable from 0.05 to 0.3 mAs in 0.05 mAs steps and from 0.3 to 1.0 mAs in 0.1 mAs steps. A safety timer set for two seconds is provided to terminate the exposure in the event that the mAs timer does not function. The exposure switch is of the deadman type and is located at the end of a cable attached to the side of the control unit (figure 1). When it is closed there is a delay of approximately five seconds before the exposure takes place. A light on the control panel indicates when X-rays are being produced and a reading appears on the mAs meter.

The Panoramix is equipped with a constant potential generator. The high voltage is half-wave rectified by a bank of semiconductor diodes and is filtered by a large capacitor within the HV transformer tank to an approximately constant potential.

Figure 1. Panoramix Model MO-200 X-ray machine

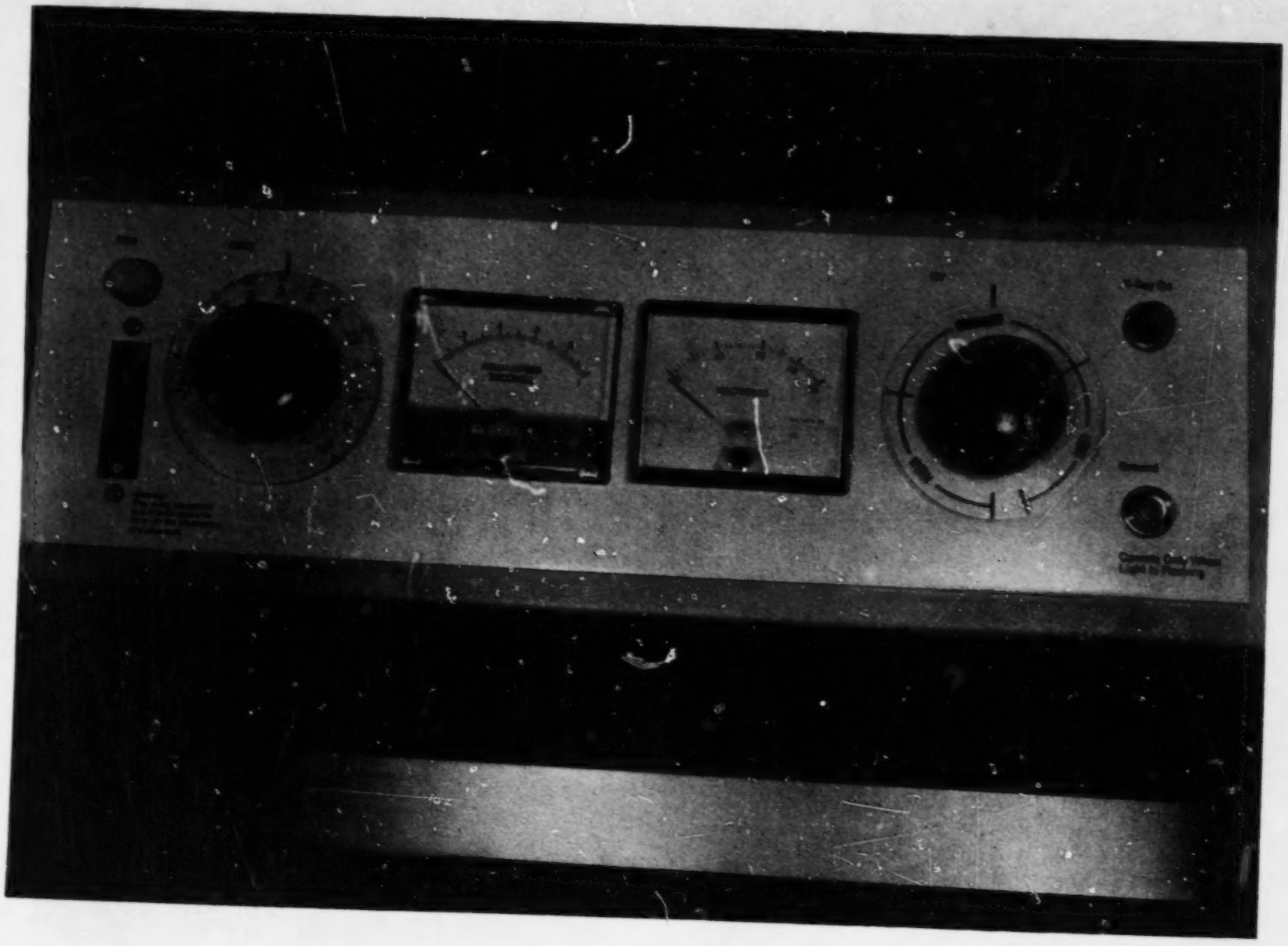


Figure 2. Panoramix control panel

The Panoramix uses an anode grounded X-ray tube which is radically different from conventional diagnostic tubes. Its major feature is its anode rod extension (figure 3). A cone-shaped anode made of copper with a tungsten apex is mounted at the end of the tube. The manufacturer claims a focal spot size of 0.1 mm. The anode is sealed into the end of the glass tube permitting an external electrical ground connection to it. The cathode is a small, indirectly heated copper tube which is precisely aligned with the anode. Except for the anode rod extension, the head is oil-insulated.

To assure exact impingement of the electron beam on the anode tip, four electro-magnets are arranged around the tube at the cathode end of the anode stem. Within the stem are four aluminum strips with external terminals leading to the beam centering circuit. Once the electron beam has been precisely centered, any deviation will be sensed by a change in the electrical balance of the four aluminum strips. This causes the fields of the electro-magnets to change, thereby realigning the beam as precisely as the original alignment was made.

The Panoramix tube is grid controlled. When the exposure switch is closed, a high negative grid bias prevents the flow of electrons from the cathode to the anode and, consequently, prevents the production of X-rays. A five second delay provides time for charging the high voltage filter capacitor and for raising the cathode to operating temperature. After this delay the grid bias is removed and the exposure takes place.

The mAs timer is a mono-stable multivibrator with an RC (resistance-capacitance) trigger circuit. The voltage developed across a resistor in the X-ray anode circuit during the exposure is applied through a series resistor to a capacitor in the timer. When the capacitor is charged to the trigger level, the multivibrator fires and terminates the exposure. The length of the exposure is controlled by selecting different series resistors, thereby changing the RC time constant.

The safety timer is a conventional thyratron timer set for two seconds. If the tube current should drop below 0.4 mA, or if the regular timer should fail for any reason, the safety timer will terminate the exposure and cause a buzzer to sound. The buzzer will also sound if any trouble causes an interlock to open.

The Panoramix is designed to emit useful X-radiation in all directions except for the shadows of the anode and the tube housing. The anode produces a cone-shaped shadow with a 90^{o} angle at the apex, leaving 270^{o} of radiation in the plane parallel to the anode stem and 360^{o} in the plane perpendicular to the stem. The amount of radiation penetrating the anode is approximately one percent of that emitted at right angles to the tube in the plane of the focal spot.

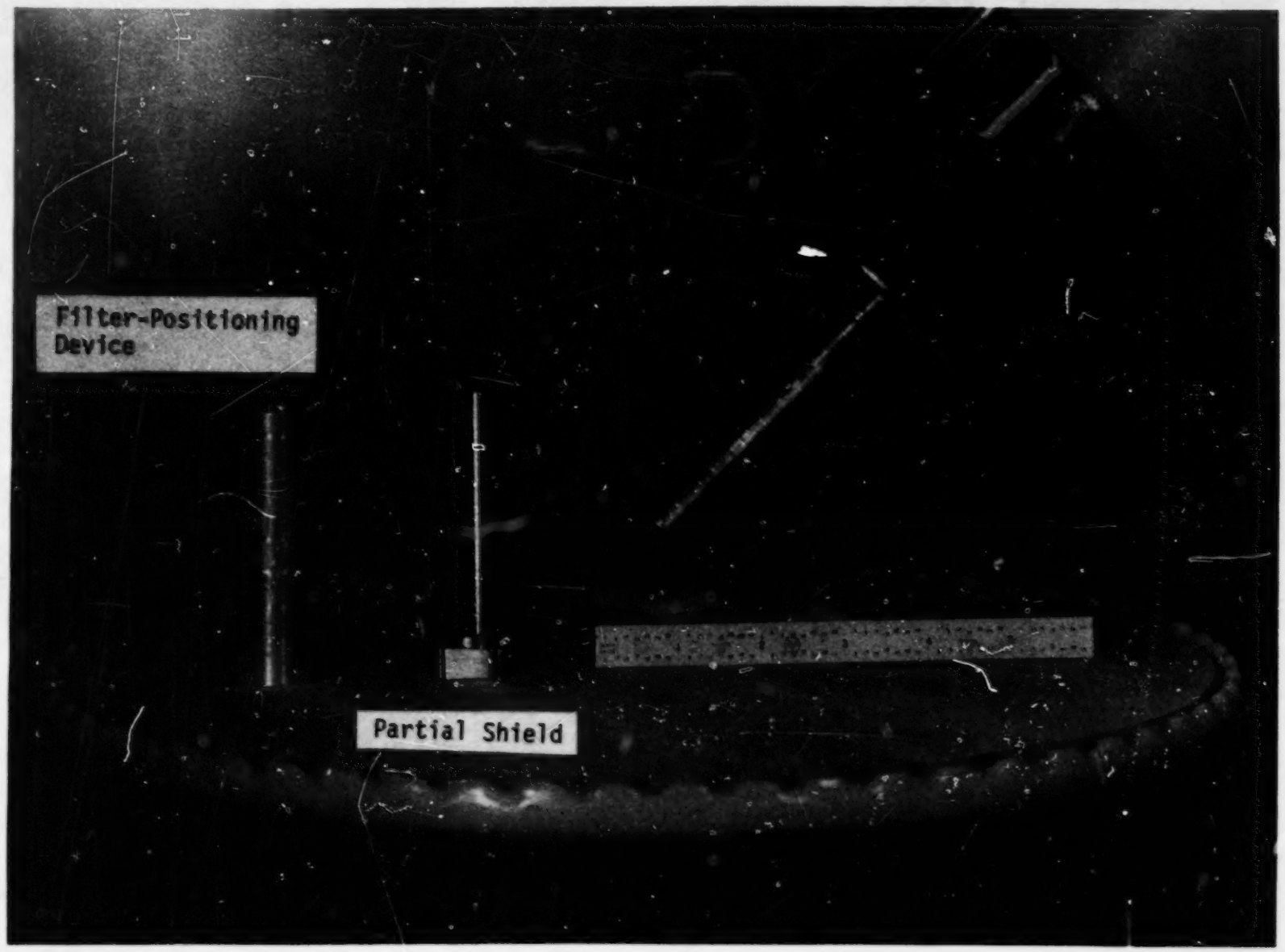


Figure 3. Detail, showing anode stem, partial shield, and extra filter

The glass anode stem of the X-ray tube is provided with an aluminum cover 1 mm thick. This cover can be removed for visual inspection of the centering coils, anode, and other components of the anode stem. The machine cannot be operated without this cover as it is part of the anode grounding circuit. The aluminum cover is intended as a filter and should not be considered a protective guard against physical damage to the tube. An additional filter of about 2 mm aluminum is provided which slips over the aluminum cover. A ring 11/32 of an inch from the end of the slip-on filter marks the position of the focal spot. A partial shield is also provided which slips over the tube cover. This shield cannot be used with the extra filter. Figure 3 shows, from left to right, the additional aluminum filter, the partial shield, and the aluminum tube cover in place over the glass anode stem.

3. PRELIMINARY TESTS

3.1 Primary Voltages

The Panoramix has provisions for different line voltage connections from 107V to 128V. The manufacturer's suggested procedure is to measure the line voltage and connect the power leads to the appropriate terminals. However, since the unit was received wired for 115V, the line voltage was set and maintained at that level by a General Radio, Type 1570-A, automatic voltage regulator throughout these tests. A Weston Model 433 AC voltmeter was connected across the primary of the high voltage transformer. The primary voltage and kV meter readings were recorded at each position of the kV selector switch and compared with the Panoramix Test Specifications. There were two positions of the selector switch below the minimum specified by the manufacturer (30 kV). The range did not extend to the top two positions (67.5 and 70 kV). Use of a higher line voltage would correct this, but it was decided to conduct all tests at the voltage specified by the manufacturer. At all other positions both the primary voltage and the kV meter were within one unit of their specified values. The results are shown in appendix A.

3.2 Line Current

The line current required by the Panoramix was measured with a Weston Model 433 AC ammeter placed between the voltage regulator and the X-ray machine. The pre-exposure current when the exposure switch was closed was slightly less than 1 ampere. The maximum current during an exposure was 3.15 amperes at an indicated 66 kV. Current requirements at different kilovoltages are given in appendix A.

3.3 Beam Centering

Before making any X-ray tests it was necessary to center the electron beam. The four aluminum centering strips described above are connected to the grid-cathode circuits of two dual triodes in the beam centering device. The four electro-magnets are in the plate circuits of these dual triodes. The electron beam was centered by adjusting the plate currents of the dual triodes until there was no change in current during an exposure. To check the beam centering the anode rod was positioned perpendicularly to a 14" x 17" Royal Blue Ready Pak film with the rod tip centered on the film and at a distance of about one inch. An exposure was made and the film was processed. The shadow of the anode appeared as a perfect circle on the film with a uniform halo of exposed area around it, diminishing in intensity from the anode area outward. From this it was assumed that the beam was properly centered.

4. kV TESTS

4.1 kV Meter Calibration

To check the accuracy of the kV meter the high voltage cable was removed from the tube head and connected to a Hallmark Standards, Inc., Model KVE 0-50 kV electrostatic voltmeter and a calibrated voltage divider (see appendix B, part b). The voltage divider drew approximately the same current as that drawn by the X-ray tube during an exposure so it represented a load similar to the tube. The two instruments were read simultaneously immediately upon closing the exposure switch -- the electrostatic voltmeter directly and the voltage divider with a calibrated oscilloscope.

The kV step interval appeared to be 2.2 kV, rather than 2.5 kV, which causes the kV meter to indicate high above 42.5 kV and low below 42.5 kV. The maximum error, when extrapolated to an indicated 70 kV in figure 4, is 3 kV. Above 60 kV, there was some corona observed at the exposed high voltage terminals which affected the accuracy of the readings. A calibration curve was plotted (figure 4) as indicated kV vs measured kV. The kV calibration data are shown in appendix B.

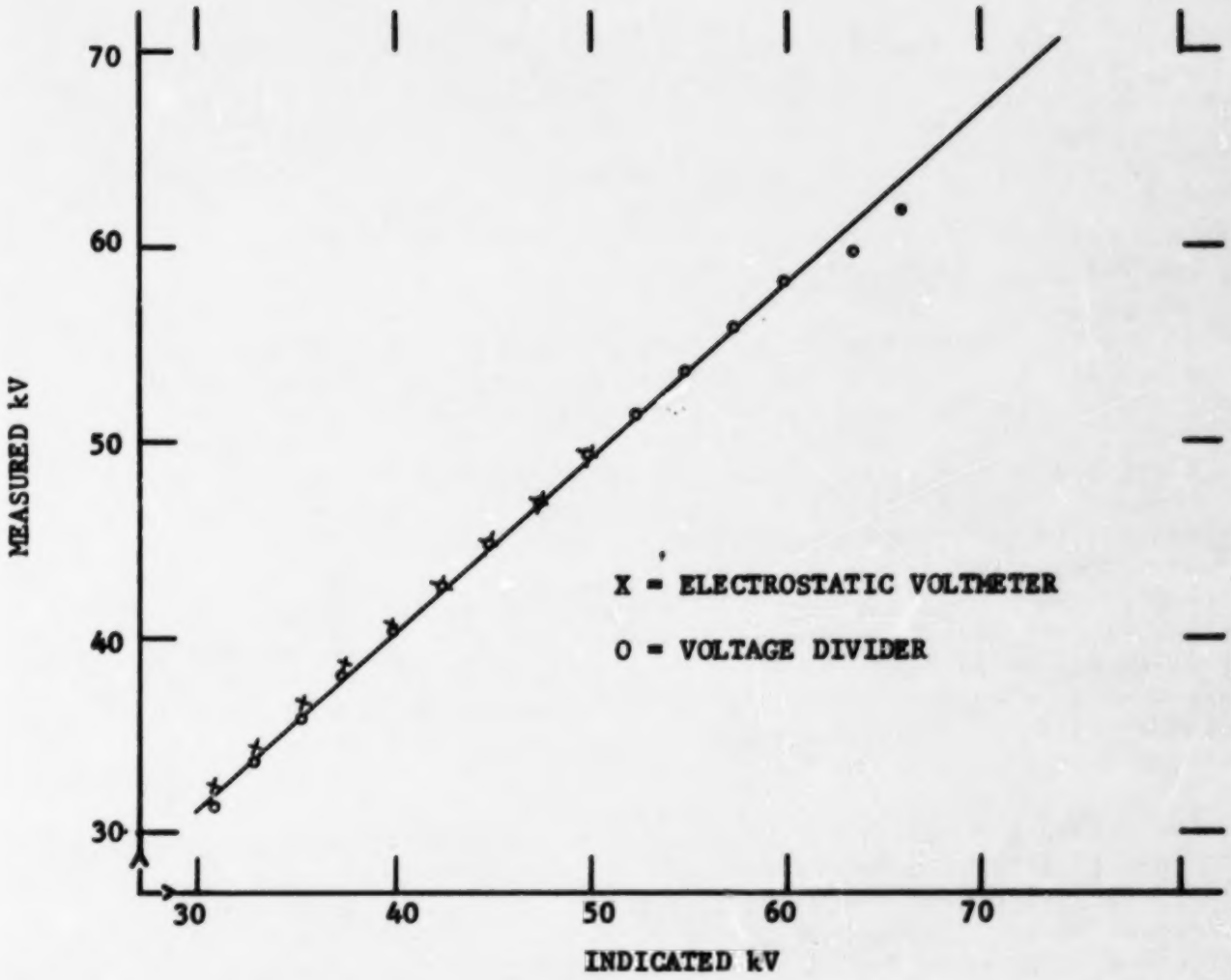


Figure 4. kV calibration

4.2 kV Variation with Line Voltage

At a given kV selector switch position some variation in kV is to be expected with variations in line voltage. Observations were made of the kV meter indication at several line voltages. The results were plotted (figure 5) as kV vs line voltage for two positions of the kV selector switch.

Unless otherwise stated, the indicated rather than measured or calibrated kV is used throughout this report.

5. mAs AND TIMER TESTS

5.1 mAs Meter Calibration

In order to determine the accuracy of the mAs meter, it was necessary to measure the tube current and the exposure duration. The mAs meter readings were also compared with the mAs control setting.

A calibrated 0-1 mA meter was placed in the low tension side of the X-ray anode circuit as directed in the Panoramix Instruction Manual. It was possible to get good current readings with 1 mAs exposures. The current was measured at several kilovoltages over the range of the unit. The results are shown in figure 6 as measured mA vs indicated kV. The Test Specifications call for a current of 0.65 mA at 50 kV and require that it remain within the limits of 0.55 to 0.75 mA from 30 kV to 60 kV. Figure 6 shows a current of 0.73 mA at 50 kV and a range of 0.59 to 0.78 mA from 30 kV to 60 kV. No change was made in the current though there is provision for adjustment.

The exposure duration was measured by using a photo-detector instrument to trigger a calibrated recording oscilloscope. The photo-detector instrument consisted of a high voltage power supply with a phototube/ fluorescent screen combination as the detector. Typical traces are shown in figure 7. The exposure duration was measured at approximately half the pulse height, ignoring the short transient spikes observable at the end of the exposure. A measurement was made for each mAs setting at 35, 50, and 66 kV. The reading of the mAs meter was also recorded for each exposure.

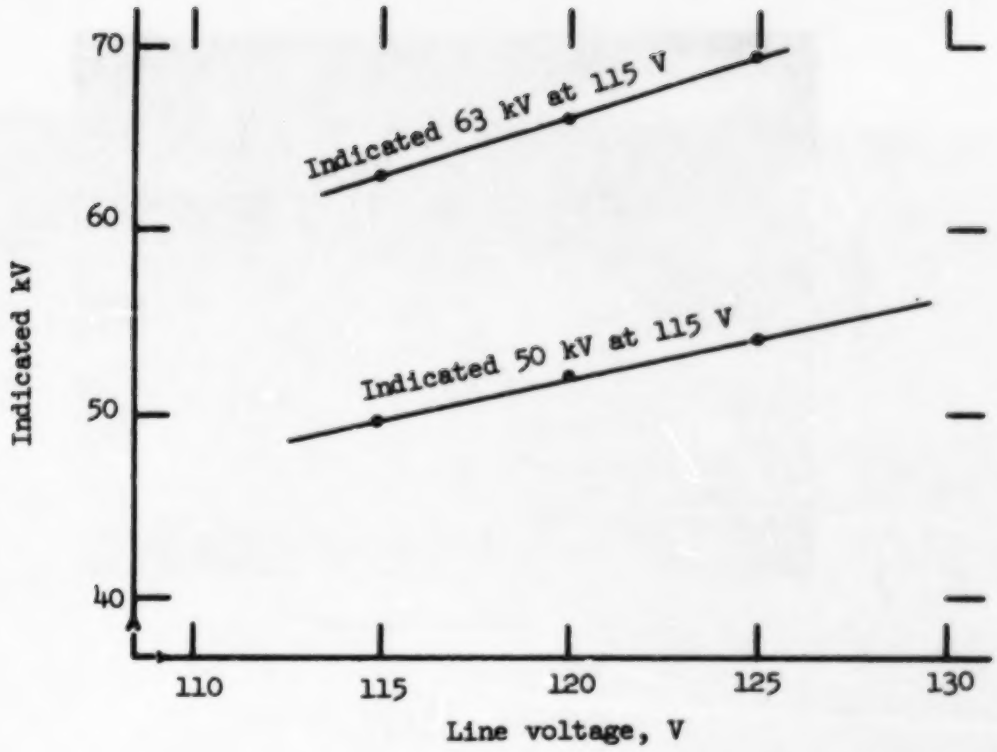


Figure 5. Variation of kilovoltage with line voltage

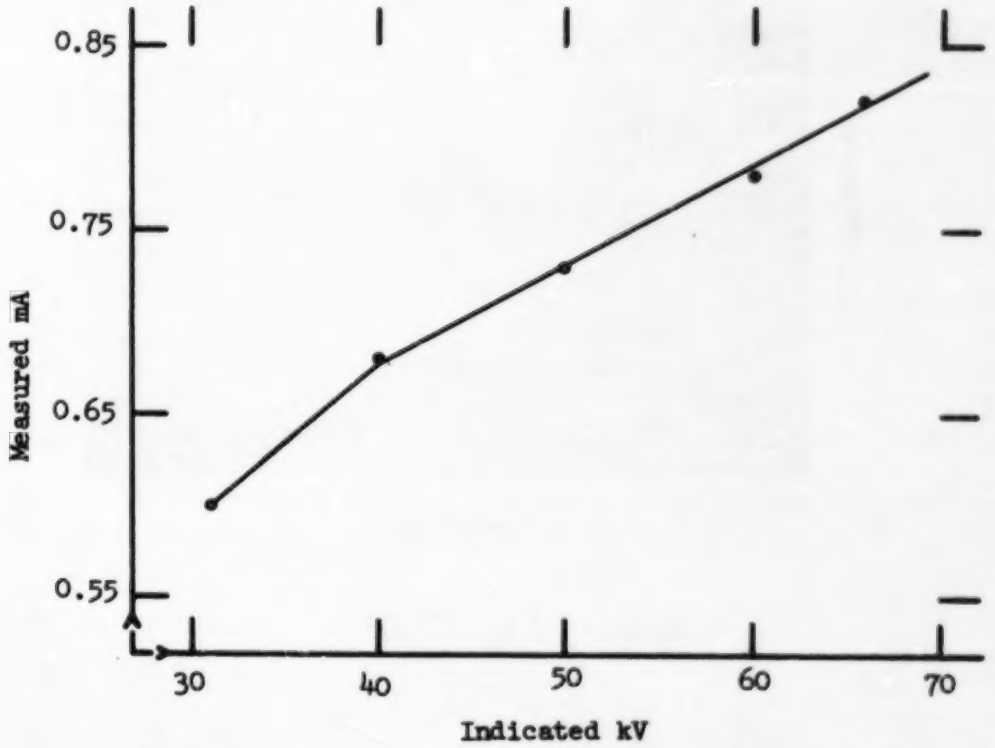
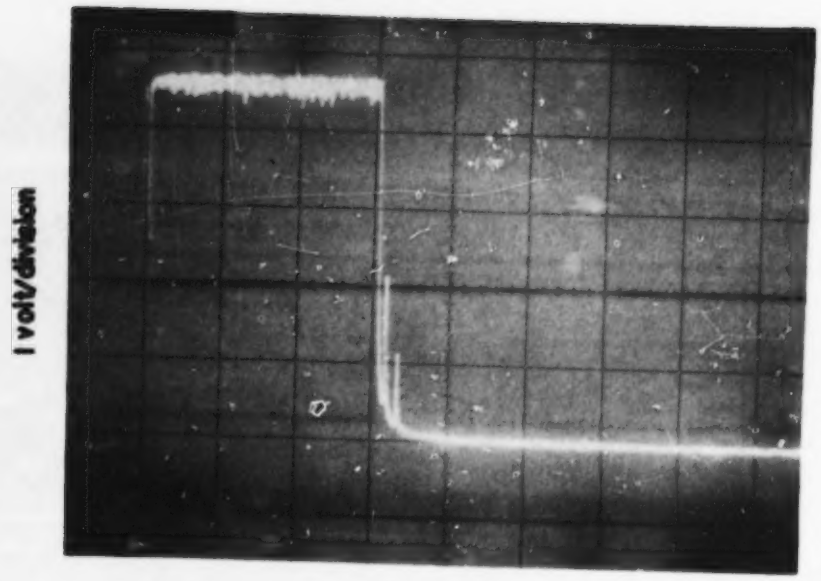
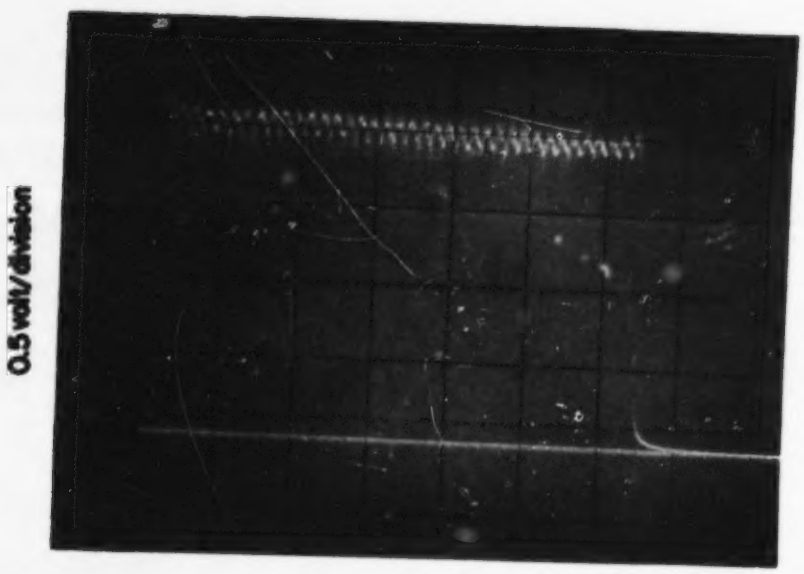


Figure 6. Variation of tube current with kilovoltage



a) 0.15 mAs, 50 kV



b) 0.5 mAs, 35 kV

Figure 7. Exposure duration

The exposure duration and the tube current (figure 6) were used to calculate the mAs at each mAs setting for each of the three kilovoltages. These values were then averaged to give a single calculated mAs for each mAs setting. Figure 8 shows calibration curves of both Indicated and Calculated mAs vs mAs Setting. The data from which these curves are plotted is in appendix C. The calculated mAs is about 80% of the mAs setting. This can be increased to 100% by ajdusting the voltage applied to the timer. The mAs meter can then be set to indicate correctly by adjusting its shunt resistor.

Unless otherwise stated, the indicated rather than measured, or calibrated, mAs is used throughout this report.

5.2 Timer Reproducibility

The timer reproducibility was checked by making ten consecutive exposures at 35, 50, and 66 kV at 0.2 mAs and measuring the exposure times. A standard deviation of 2% was calculated.

5.3 Exposure Reproducibility

The Philips Model 37488 ion chamber was placed normal to the anode stem at a distance of four inches from the focal spot with the long axis of the chamber parallel to the anode stem. Twenty exposures each were made at 50 kV and 0.05, 0.1, 0.2, and 0.3 mAs and ten exposures each at 0.5, 0.7, and 1.0 mAs. The estimated standard deviations of the exposures are shown in table 1 below.

Table 1. Exposure reproducibility

mAs setting	Standard deviations of exposures
0.05	5.2%
0.1	2.7%
0.2	2.2%
0.3	1.1%
> 0.3	< 1.0%

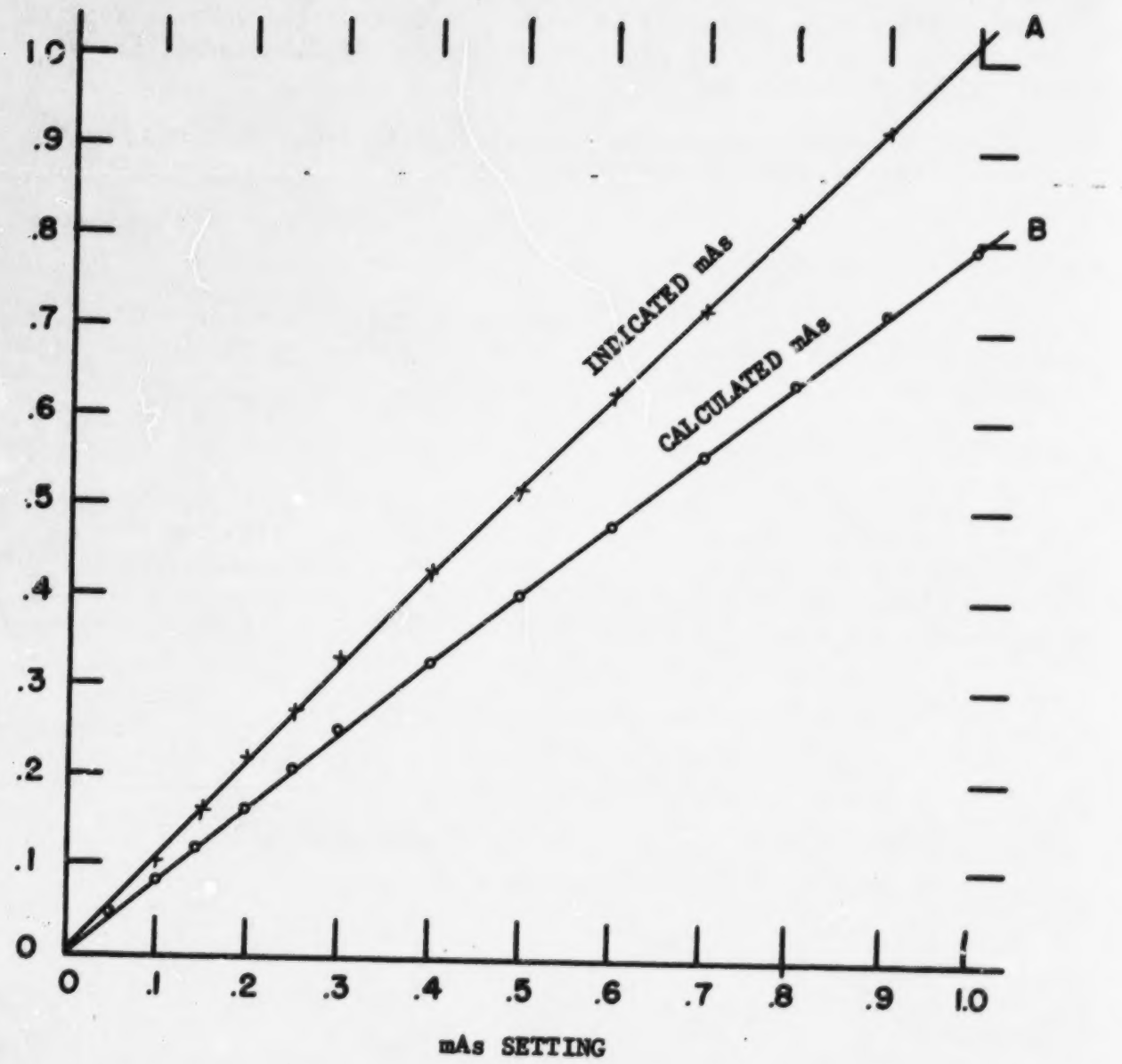


Figure 8. mAs calibration

The above exposures were averaged and used to calculate mR per mAs for each mAs setting. The results were normalized to 100 mR/mAs at the 0.05 mAs setting and plotted as Relative mR/mAs vs mAs Setting (figure 9). The high mR/mAs values observed for low mAs exposures are probably systematic errors since they were calculated from average exposures. These values are felt to be the result of either a surge in the mA or inaccuracy in the timer for short exposures plus measurement error.

5.4 Back-up Timer

The back-up timer was tested by bypassing the mAs meter to ground, thus removing the regular mAs timer from the circuit. After two seconds, the buzzer sounded and the exposure was terminated.

6. HALF-VALUE LAYER

The half-value layer was measured using the apparatus diagrammed in figure 10. "A" and "B" are lead sheets with 3/8" and 1" apertures, respectively. The aluminum filters are added half-way between the focal spot and the detector at "B" as shown in the diagram. A Philips Universal Dosemeter with the Model 37488 ion chamber probe was used as the radiation detector. The apertures were centered on the focal spot and the detector was positioned with its long axis parallel to the central ray, taking care that it was completely covered by the beam. Measurements were made at tube angles of 0^{o}, 30^{o}, and 45^{o} at 50 kV and 63 kV. The 0^{o} position is represented by the solid lines in figure 10 and the 45^{o} position by the dotted lines. Attenuation curves were plotted and used to find the half-value layers.

The results are shown in table 2. The beam size, checked with a fluoroscopic screen, was found to just cover the detector. The results obtained with the 1" aperture were therefore accepted as reasonable approximations of the unique half-value layers and used to calculate the homogeneity coefficients.

The half-value layers at 0^{o} and 30^{o} are approximately the same, whereas those at 45^{o} are considerably greater (table 2). It is felt that this result can be explained as follows: as the tube is rotated from 0^{o} towards 45^{o}, as illustrated in figure 10, the beam becomes harder because the angle, and therefore the distance, of penetration through the aluminum tube cover is increasing. On the other hand, at a tube angle of 45^{o} X-rays are being emitted normal to the surface of the anode as a result of its conical shape. As the tube is rotated back towards 0^{o}, self absorption in the anode increases and the beam becomes harder. This is the heel effect observed in conventional tubes. Since these effects act in opposite directions, one would expect the half-value layer to have a minimum at some angle and to increase as the tube is rotated in either direction from that angle. The results in table 2 suggest that the minimum half-value layer may be between 0^{o} and 30^{o}. Laboratory measurements of X-ray output show the maximum intensity to be near 20^{o}.

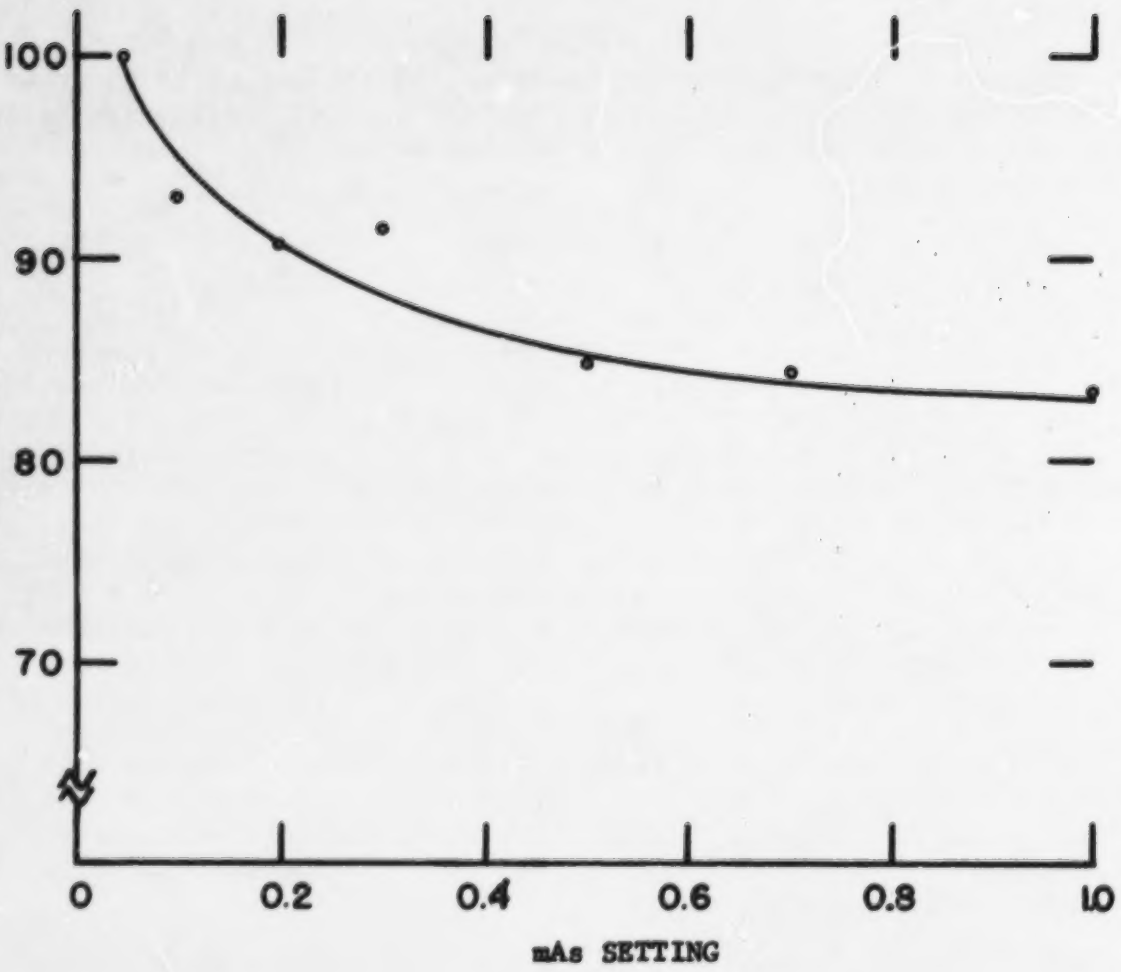


Figure 9. Radiation output (50 kVcp)

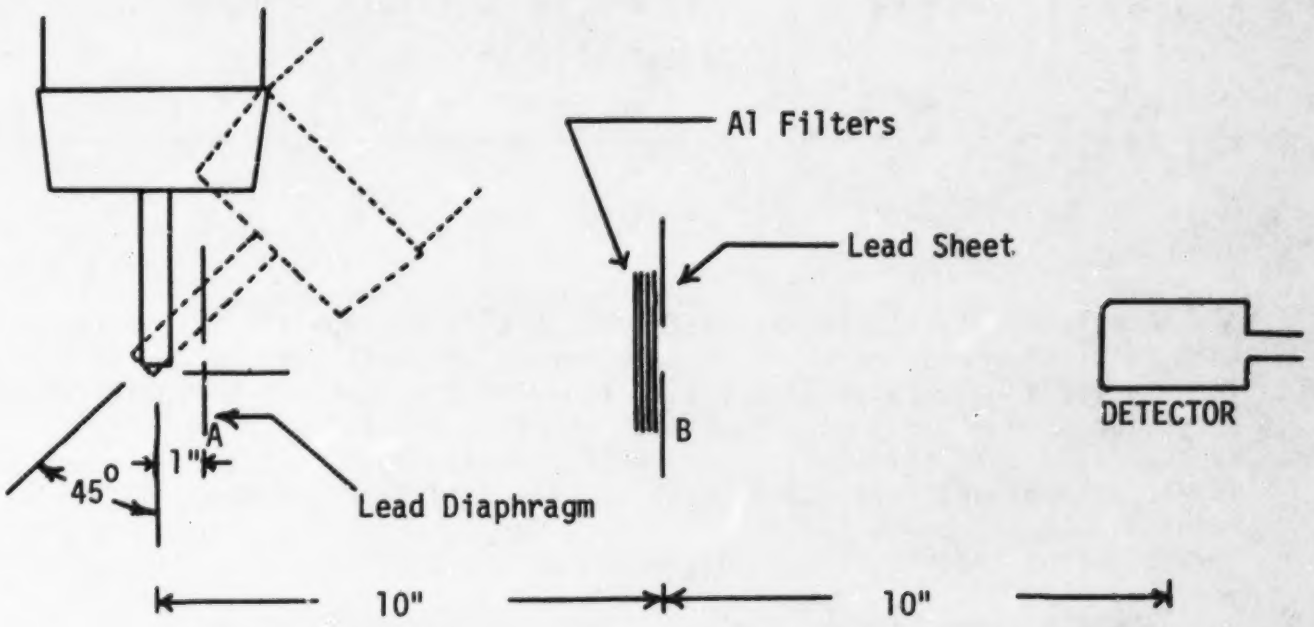


Figure 10. Diagram of half-value layer apparatus

Table 2. Half-value layer

	1st HVL (mm Al)			2nd HVL (mm Al)			Homogeneity Coefficient		
	0^o	30^o	45^o	0^o	30^o	45^o	0^o	30^o	45^o
50kV	1.53	1.56	1.77	2.17	2.19	2.43	0.71	0.71	0.73
63kV	1.84	1.85	2.10	2.93	2.92	3.09	0.63	0.63	0.68

7. INHERENT FILTRATION

The inherent filtration, which consists of attenuation in the target, the glass tube, and the aluminum tube cover, was estimated by comparing the Panoramix half-value layers with those of the constant potential, beryllium window X-ray unit used with the Free Air Ion Chamber (FAIC) system. The FAIC calibration data of August 19, 1968, had been plotted as HVL vs inherent filtration at 10 kV intervals over the range of the machine. The inherent filtration values for the Panoramix were read directly from these curves. They are shown in table 3.

The thickness of the aluminum tube cover was measured and found to be 1.02 mm.

Table 3. "Effective" inherent filtration (mm Al)

	Tube Angles		
	0^o	30^o	45^o
50kV	1.81	1.88	2.38
60kV	1.86	1.88	2.33
Average	1.84	1.88	2.36

8. X-RAY OUTPUT

8.1 Primary Beam

The Panoramix produces 360° of radiation perpendicular to the anode stem and 270° parallel to it. Extruded LiF rods approximately 1 mm x 6 mm were used to measure the X-ray field patterns in both planes using the apparatus shown in figure 11. They were calibrated using a G.E. Maximar-100 with kilovoltages and filtration similar to those of the Panoramix. The LiF rods were mounted on construction paper in eight concentric circles, one inch apart, along selected radials with the focal spot at the center. The spiral pattern shown in figure 11 was used in the perpendicular plane to prevent shielding of the more distant dosimeters by the nearer ones. In the parallel plane, a cutout was made in the paper to accommodate the tube head. Exposures were made at 50 kV.

The LiF dosimeters were read and the data were plotted as mR vs distance along each radial. These curves were used to construct the iso-exposure curves in figures 12 and 13. Figure 12 is the plane perpendicular to the anode stem and figure 13 is the plane parallel to the anode stem. Both are centered on the focal spot. Note that exposure values close to the anode are not in complete agreement in the two figures. Near the tube the exposure rate is decreasing very rapidly with distance, resulting in uncertainty in measurement due to the difficulty of reproducing dosimeter placement at these short distances. For example, at the tube surface, normal to the anode the exposure rate at 50 kV is approximately 47 R/mAs (figure 14); whereas at an inch from the anode it is less by a factor of ten.

8.2 Contact Exposures

Exposures at the surface of the X-ray tube were estimated by positioning LiF dosimeters directly on the surface with rubber bands. One ring of five dosimeters was centered over the focal spot and three additional rings were situated at 3/4" intervals along the tube. Exposures were made at 40 kV, 50 kV, and 60 kV on the bare tube, at 50 kV and 60 kV on the slip-on aluminum filter, and at 50 kV on the slip-on partial shield.

Figure 14 shows the exposures on the bare tube and the shield; figure 15 shows the exposures on the added filter.

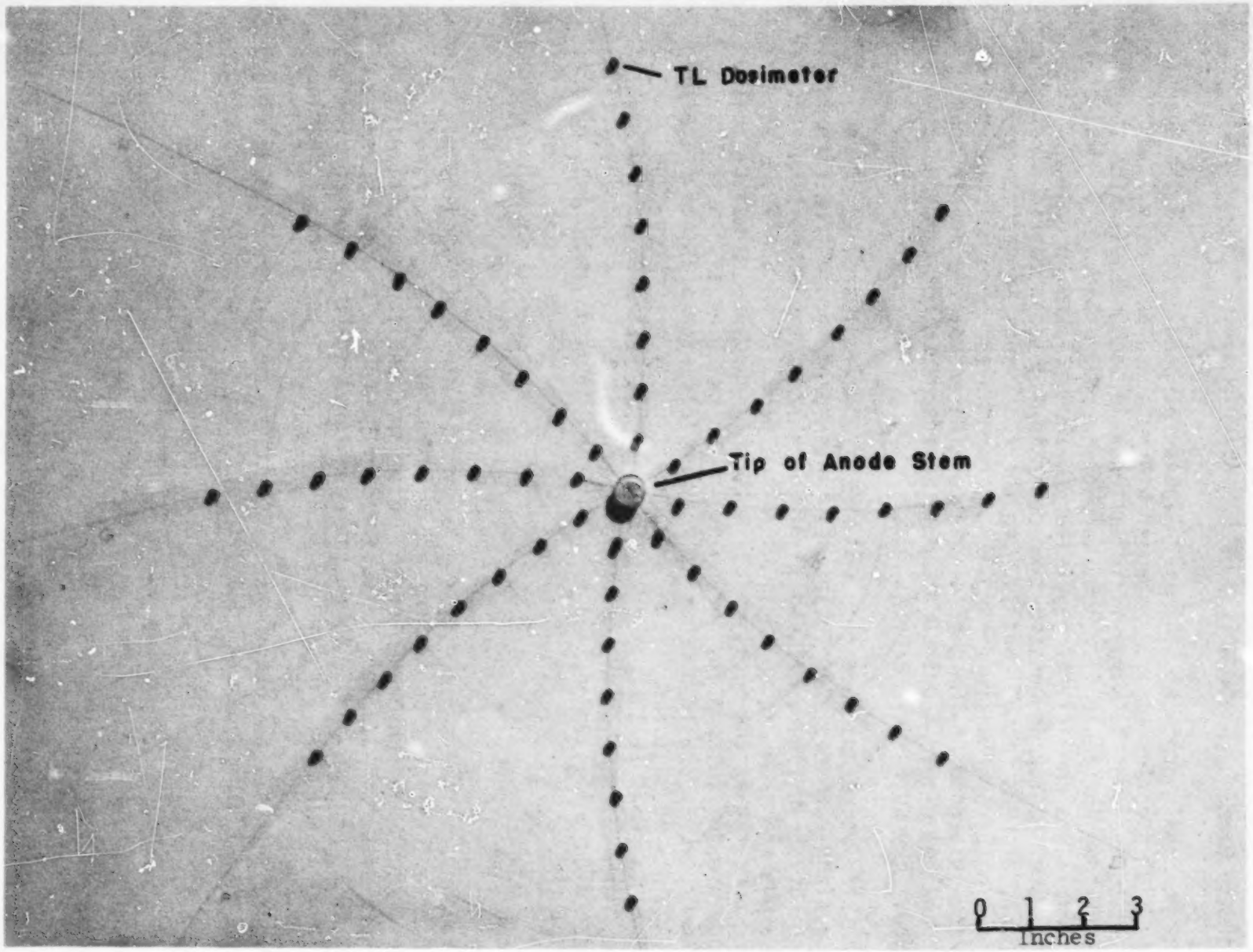


Figure 11. Placement of dosimeters for measurement of air exposures

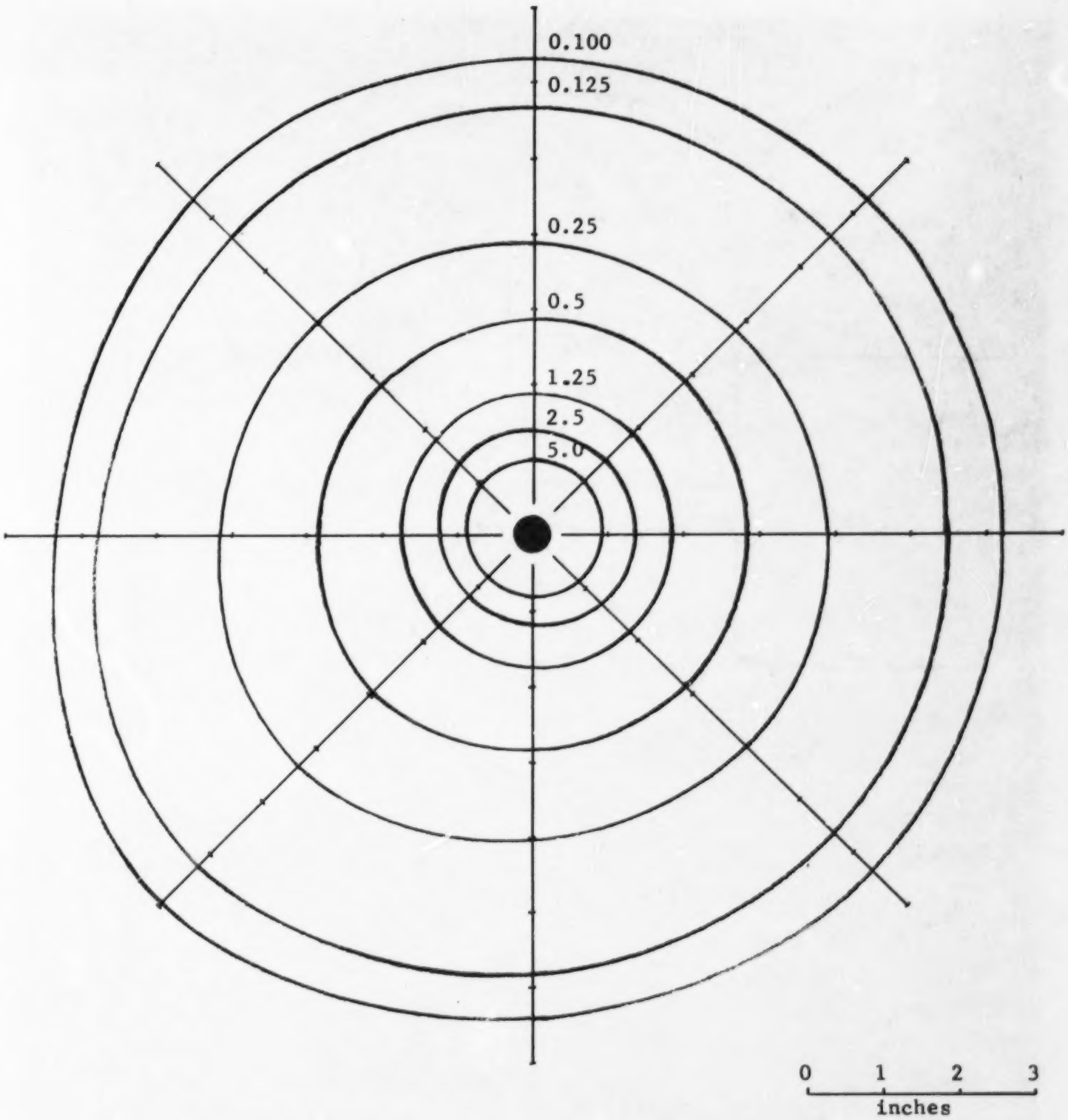


Figure 12. Panoramix iso-exposure curves in air perpendicular to anode stem. R/mAs at 50 kVcp.

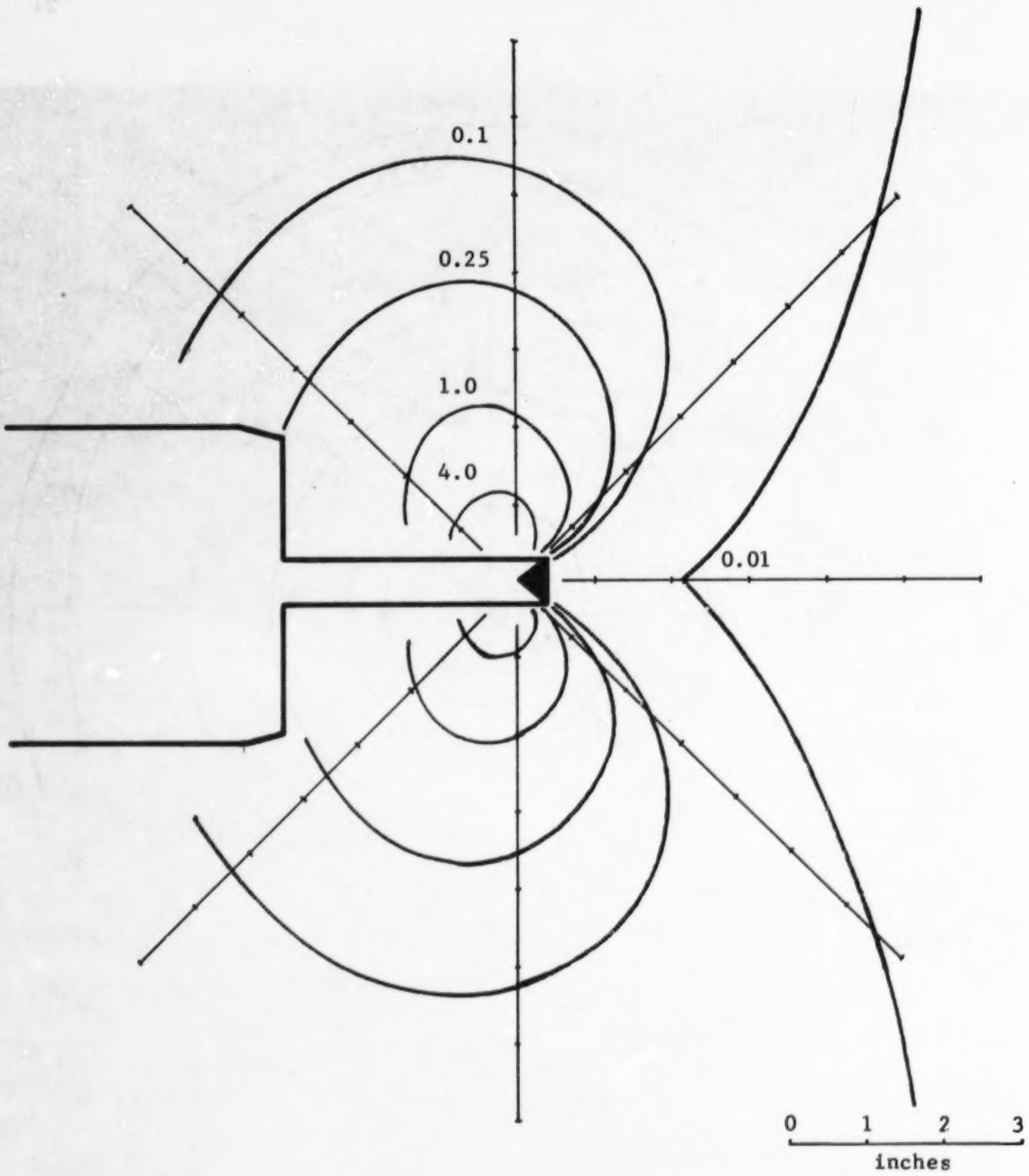


Figure 13. Panoramix iso-exposure curves in air parallel to anode stem. R/mAs at 50 kVcp.

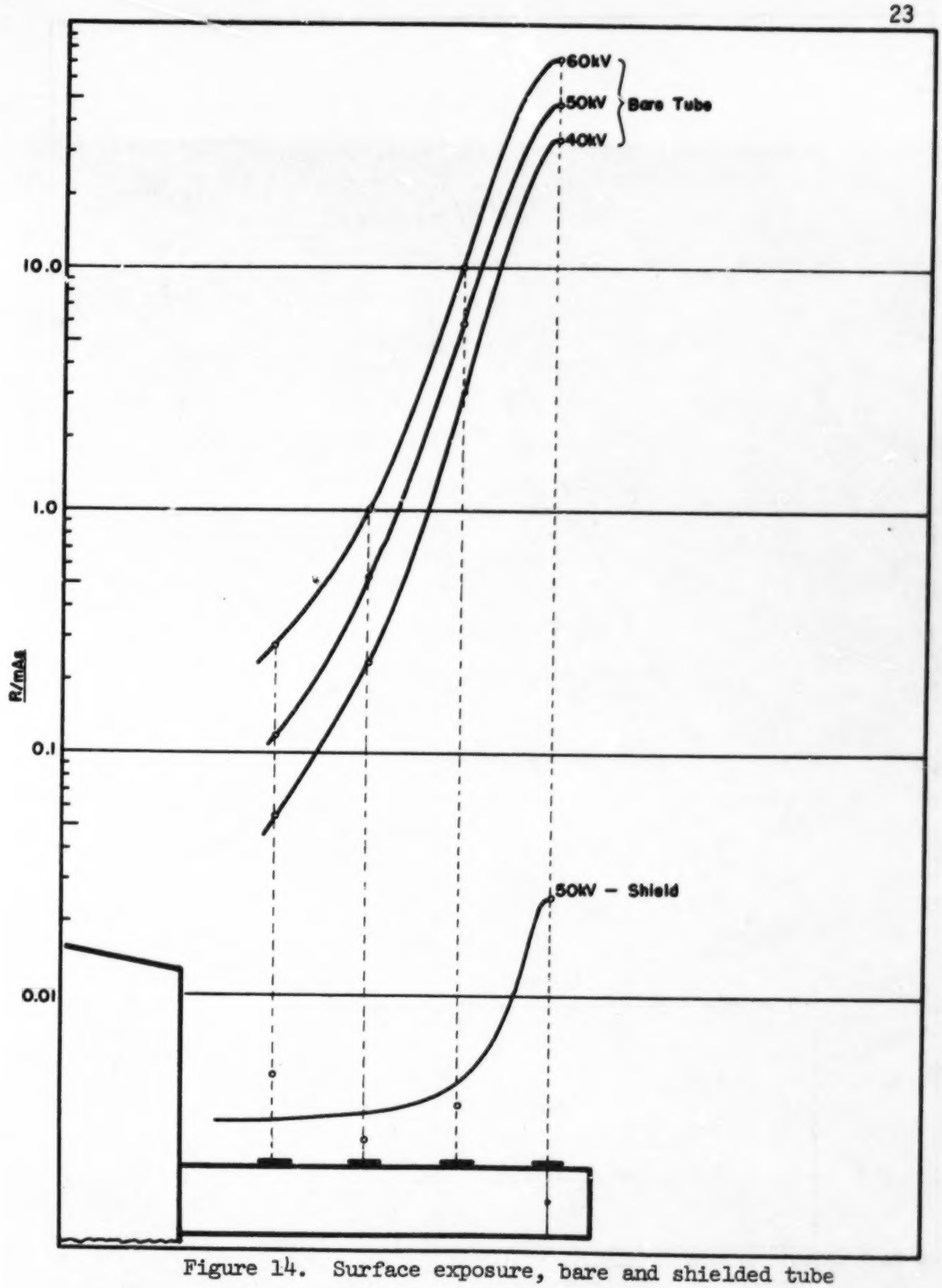


Figure 14. Surface exposure, bare and shielded tube

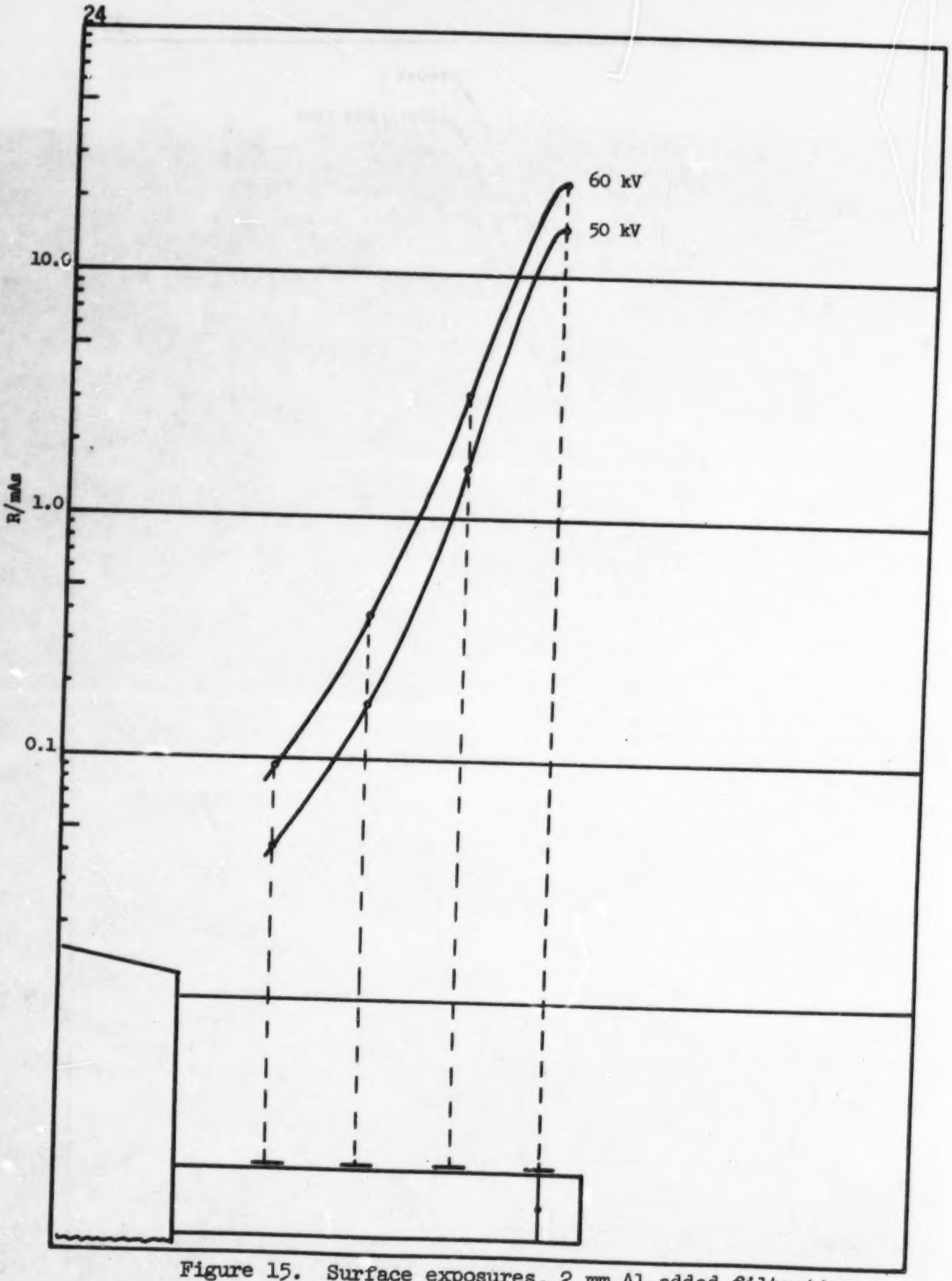


Figure 15. Surface exposures, 2 mm Al added filtration

8.3 Radiation Exposure in Vicinity of a Phantom

Using a dental X-ray technique, an estimate of the levels of radiation exposure in the vicinity of a phantom was made. LiF dosimeters were positioned at 30° intervals at distances of 9" from the focal spot as shown in figure 16. The cardboard dosimeter holder was centered on the focal spot around the head of the phantom about two inches above the anode rod stem and parallel to it (figure 16). One hundred exposures were made at 60 kV and 1 mAs; the results are shown in figure 17 in mR/0.25 mAs. An exposure of 0.25 mAs is typical for dental film, though rather longer than usual for 60 kV.

9. FOCAL SPOT

ICRU standard pinholes* of 0.030 mm and 0.075 mm diameter were used to produce photographic images of the focal spot. These are shown in figure 18. The pinhole and film were positioned perpendicular to the anode stem in line with the focal spot at the distances shown.

The Panoramix focal spot size is 0.1 mm according to the specifications, though there is no indication as to how this was measured. If the vertical height of images e - h in figure 18 is estimated to be 0.1 cm, the calculated height of the focal spot is 0.16 mm as viewed perpendicularly to the vertical axis of the cone (see appendix D). This is by no means presented as an accurate measure of the focal spot size since it is not clear what dimension is to be measured, the pinhole is large compared to the size of the image, and it is difficult to measure the photographic image accurately. The low output of the machine makes it difficult to obtain much magnification without a very large number of exposures.

In spite of these problems, the unusual shape of the focal spot is quite clear and its size appears to be on the order of that claimed by the manufacturer.

10. ELECTRICAL HAZARDS

The manufacturer states that the unit should be used with a grounded line supply and should under no circumstances be operated without a safe ground. A blinking light on the right side of the control panel indicates a safe ground connection.

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* NBS Handbook #89, page 1.

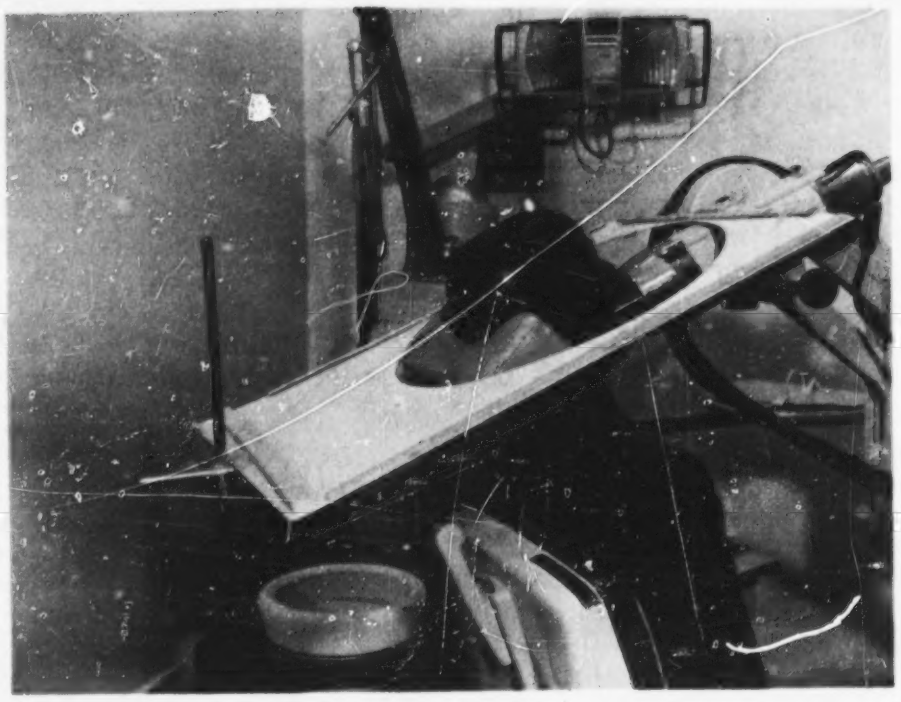

Figure 16. Radiation in the vicinity of a phantom
(LiF dosimeters placed at the edge of circular cut-out)

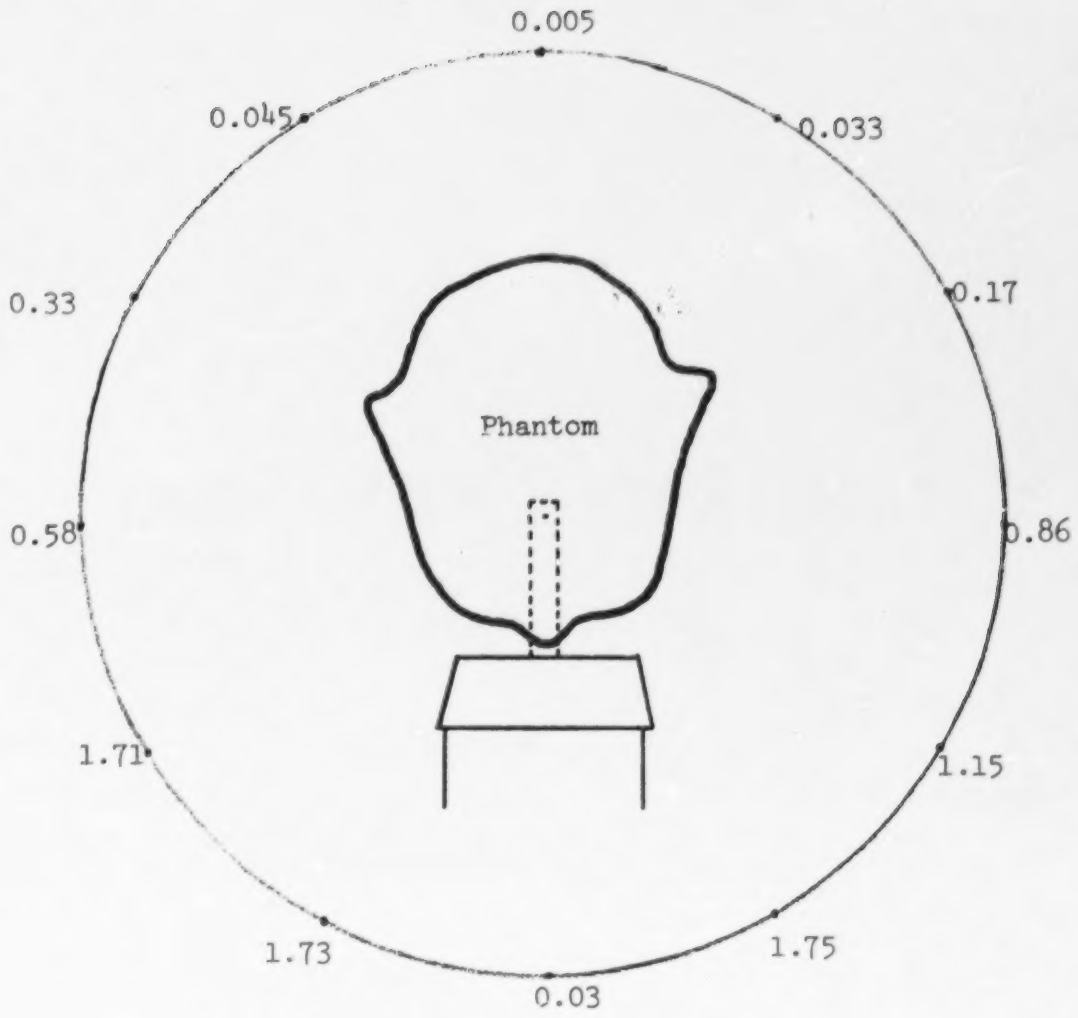

Figure 17. Exposures in mR/0.25 mAs at 60 kVp, at a radius of 9" and approximately 2" above the plane of the anode stem. Tube positioning is for a single mandibular-maxillary radiograph (see figure 16).

a.

100mAs, 5/10

0.030mm

b.

45mAs, 10/20

0.030mm

c.

12mAs, 5/10

0.030mm

d.

12mAs, 5/10

0.075mm

e.

5 mAs

f.

20 mAs

g.

30 mAs

h.

40 mAs

e-h: all 5/25, 0.030mm

KEY

Film:	a= Type M; b-h=Royal Blue
Pinhole size:	0.030mm & 0.075mm
Distances,x/y:	x=source to pinhole, cm y=pinhole to film, cm
Kilovoltage:	66kV

Figure 18. Panoramix focal spot

The X-ray machine was intentionally connected to the 115 volt line with the ground terminal floating. Under this condition the ground indicator light did not blink, thus correctly indicating the faulty ground connection. An attempt was then made to generate X-rays with the unit and it was found to operate normally. Since the manufacturer feels it is necessary to caution the operator against use of the unit without proper ground connection, the use of only a blinking light requiring operator observation appears to be an insufficient safety device.

11. EXPOSURE SWITCH CORD

NCRP Report #33, recommends that the operator be able to stand at least six feet from the patient, the X-ray tube, and the useful beam while using mobile radiographic equipment. Since use of the "Panoramix" may involve an uncollimated beam, the requirement that the operator stand at least six feet from the useful beam may not be adequate to meet the intent of Report #33.

12. MINIMUM SOURCE-SKIN DISTANCE

Use of this special purpose machine requires exposures to be made while in contact with the body. The NCRP recommends that a target-to-skin distance of not less than seven inches be used for dental radiographic units operating above 50 kVp and not less than four inches be used for units operating below 50 kVp (NBS Handbook 76). A minimum of 12 inches is recommended for medical radiographic units (NCRP Report No 33). It must be assumed that these recommendations are not applicable to the Panoramix since rigid enforcement would nullify the intended advantage of the machine. Special purpose machines,therefore, must be evaluated in terms of the radiation exposures associated with the type of operation necessary to realize the maximum benefit from their use.

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APPENDIX A

a) HV primary and kV meter measurements

AC Volts		kV Meter	
Specified	Observed	Specified	Observed
-	66.5	-	<30
-	71	-	<30
76	76	30	31
81	81	32.5	33
86	86	35	35.25
91	91	37.5	37.5
96	96	40	40
101	101	42.5	42.25
106	106	45	44.5
111	110.5	47.5	47
116	115.5	50	49.5
121	120.5	52.5	52.25
126	125.5	55	55
131	130.5	57.5	57.5
136	135.5	60	60
141	140.5	62.5	63
146	145.5	65	66
151	-	-	-
156	-	-	-

b) Line current measurements

kV	Maximum amperes
31	1.7
40	2.0
49.5	2.4
60	2.85
66	3.15

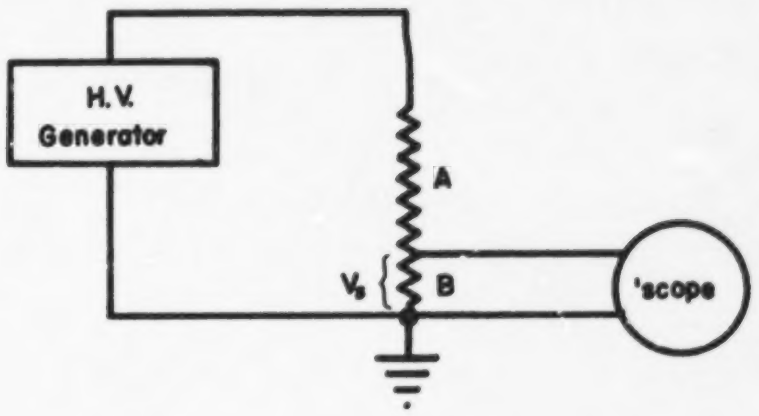
APPENDIX B

a) kV calibration

Nominal kV	kV meter	Voltage Divider		Electrostatic Voltmeter
		Measured Volts, V_B	Calculated kV	Measured kV
-	30	3.6	26.8	28
-	30	3.9	29.0	30
30	31	4.2	31.2	32.2
32.5	33	4.5	33.5	34.3
35	35.5	4.8	35.8	36.6
37.5	37.5	5.1	38.0	38.7
40	40	5.4	40.2	40.7
42.5	42.5	5.7	42.5	42.5
45	45	6.0	44.7	44.8
47.5	47.5	6.3	46.9	47.1
50	50	6.6	49.2	49.1
52.5	52.5	6.9	51.4	-
55	55	7.2	53.6	-
57.5	57.5	7.5	55.9	-
60	60	7.8	58.1	-
62.5	63.5	8.0	59.6[a]	-
65	66	8.3	61.8[a]	-

[a]Measurements in error as a result of corona discharge at the HV terminals.

b) Voltage divider



$$A + B = 74 \times 10^6 \Omega$$

$$B = 9960 \Omega$$

$$kV = \frac{(A+B)\,V_B}{B \times 10^3}$$

$$kV = 7.45\ V_B$$

APPENDIX C

a) Tube current

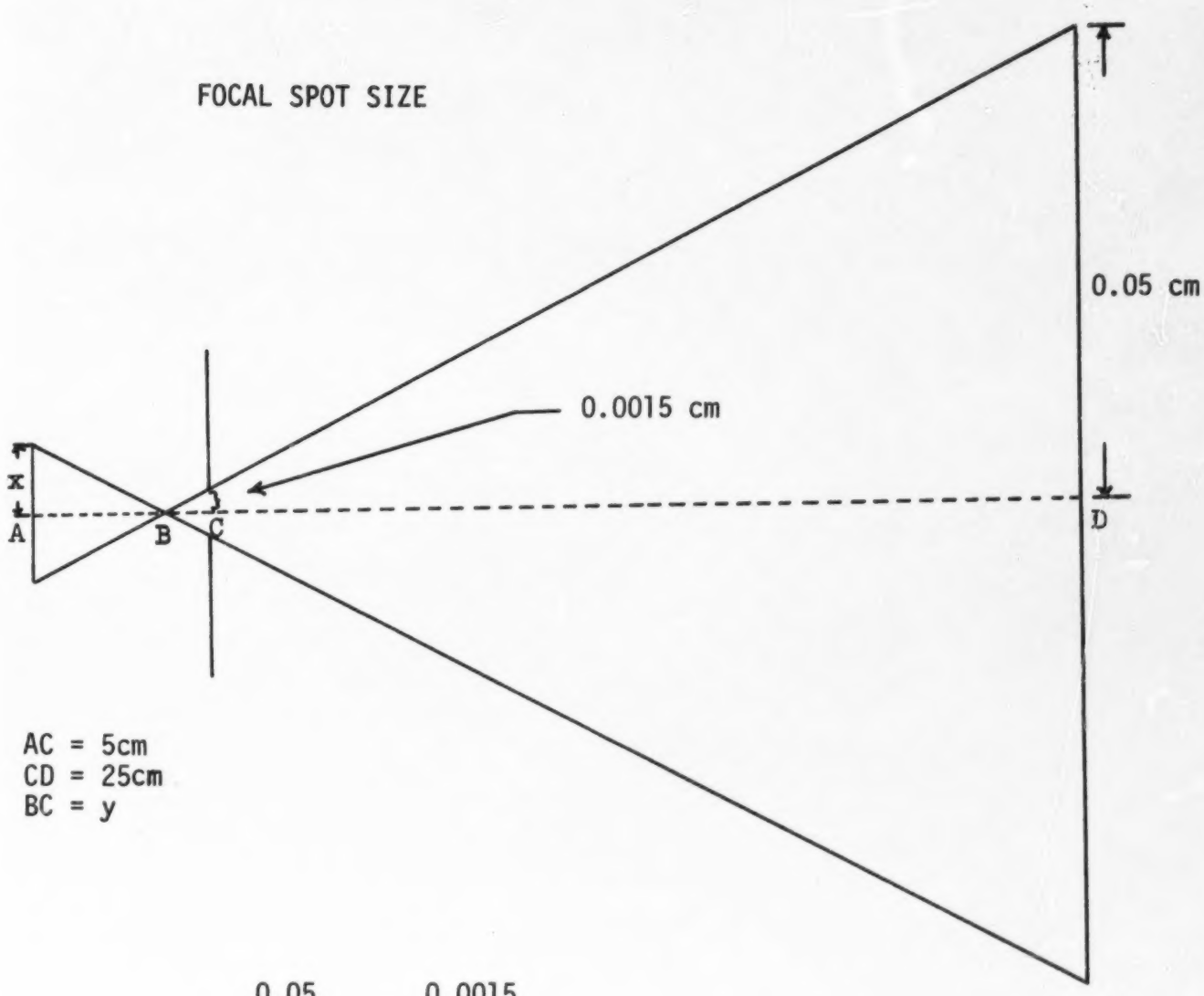
kV	mA
31	0.60
40	0.68
50	0.73
60	0.78
66	0.82

b) mAs calibration

mAs read				mAs calculated				Exposure length (msec)		
mAs set	35 kV	49 kV	66 kV	35 kV	49 kV	66 kV	Aver-age	35 kV	49 kV	66 kV
0.05	0.05	0.05	0.06	0.041	0.042	0.048	0.043	64	57	58
0.1	0.10	0.10	0.11	0.078	0.076	0.085	0.080	122	104	104
0.15	0.15	0.16	0.16	0.115	0.113	0.119	0.116	180	155	145
0.2	0.22	0.22	0.22	0.160	0.160	0.160	0.160	250	210	195
0.25	0.27	0.27	0.28	0.211	0.197	0.205	0.204	330	270	250
0.3	0.33	0.33	0.33	0.253	0.234	0.254	0.247	395	320	310
0.4	0.43	0.43	0.42	0.333	0.314	0.324	0.324	520	430	395
0.5	0.52	0.52	0.53	0.400	0.387	0.410	0.402	640	530	500
0.6	0.62	0.63	0.62	0.486	0.467	0.492	0.482	760	640	600
0.7	0.71	0.72	0.72	0.563	0.540	0.574	0.559	880	740	700
0.8	0.81	0.82	0.82	0.640	0.620	0.656	0.639	1000	850	800
0.9	0.91	0.92	0.92	0.720	0.700	0.738	0.719	1120	960	900
1.0	1.0+	1.0+	1.0+	0.790	0.780	0.803	0.791	1240	1070	980

APPENDIX D

FOCAL SPOT SIZE



AC = 5cm
CD = 25cm
BC = y

$$\frac{0.05}{25 + y} = \frac{0.0015}{y}$$

$$y = 0.775 \text{ cm}$$

$$\frac{x}{5 - y} = \frac{0.0015}{0.775}$$

$$x = 0.008 \text{ cm}$$

$$d = 2x = \underline{0.16 \text{ mm}}$$

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This report describes physical measurements on the Panoramix X-ray machine as a partial basis for a radiological health evaluation of this unit. The results of measurements to determine the accuracy of kilovoltage, timer, and current calibrations and an analysis of the radiation output, distribution, and intensity are presented. Comments are made regarding electrical hazards and the applicability of certain of the NCRP recommendations for medical and dental X-ray machines.

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Panoramic radiography

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